

Final Technical report

NASA Grant NAG5-7480

Awarded for observations with the Rossi X-ray Timing Explorer
(RXTE Program 30269)

Title: BL Lacs in X-ray Outburst

P.I. Dr. Ronald A. Remillard (M.I.T.)

M.I.T. OSP Account 6708400

CoInvestigators:

C. Megan Urry (Space Telescope Science Institute)
Felix Aharonian (MPE Heidelberg, GERMANY), Elena Pian (CNR, ITALY),
Rita Sambruna (Penn State U.), and Paolo Coppi (Yale U.).

Summary of the Investigation and Results

In response to outburst alerts from the RXTE All Sky Monitor, we conducted a series of pointed RXTE observations of the BL Lac object Mkn 421. The observations constitute 11 groups of exposures occurring between 1998 Feb 26 and 1998 July 25. These data sample a wide range in source brightness, ranging from 2.4 to 32 mCrab ($1.0 \text{ mCrab} = 2.4 \times 10^{-11} \text{ erg/s/cm}^2$ at 2-10 keV). On June 3-4, we witnessed the decay of a particularly intense flare, as the flux dropped from 32 to 16 mCrab in a 4.0 hr period.

The data were combined with contemporaneous observations by other X-ray observers, and with observations at TeV frequencies from ground-based Cerenkov telescopes, and the results were published by Takahashi et al (2000).

Publication Abstract:

We conducted a multifrequency campaign for the TeV blazar Markarian 421 in 1998 April. The campaign started from a pronounced high-amplitude flare recorded by BeppoSAX and Whipple; the ASCA observation started 3 days later. In the X-ray data, we detected multiple flares, occurring on timescales of about 1 day. ASCA data clearly reveal spectral variability. The comparison of the data from ASCA, the Extreme Ultraviolet Explorer, and the Rossi X-Ray Timing Explorer indicates that the variability amplitudes in the low-energy synchrotron component are larger at higher photon energies. In TeV and gamma-rays, large intraday variations—which were correlated with the X-ray flux—were observed when results from three Cerenkov telescopes were combined. The rms variability of TeV and gamma-rays was similar to that observed in hard X-rays, above 10 keV. The X-ray light curve reveals flares that are almost symmetric for most cases, implying that the dominant timescale is the light crossing time through the emitting region. The structure function analysis based on the continuous X-ray light curve of 7 days indicates that the characteristic timescale is ~ 0.5 days. The analysis of ASCA light curves in various energy bands appears to show both soft (positive) and hard (negative) lags. These

may not be real, as systematic effects could also produce these lags, which are all much smaller than an orbit. If the lags of both signs are real, these imply that the particle acceleration and X-ray cooling timescales are similar.

References:

"Complex Spectral Variability from Intensive Multi-wavelength Monitoring of Mrk421 in 1998", T. Takahashi, et al. 2000, Astrophysical Journal, 524, L105

poster at the 19th Texas Symposium on Relativistic Astrophysics, Dec. 14-18, 1998

"The 1998 X-ray Outbursts in Mkn 421",
R. Remillard, M. Urry, F. Aharonian, E. Pian, R. Sambruna, & P. Coppi.

Figure 1:

The X-ray light curve (2-10 KeV) of Mkn 421 from RXTE Program 30269, which covered the time interval 1998 Feb. to Aug. The data from the RXTE ASM are displayed with "x" symbols, and the pointed observations with the RXTE PCA instrument are shown as filled triangles. The PCA results confirm the substantial (factor of 2) variations that may occur on time scales less than 1 day.

Figure 2:

Profile of the 8th observation (see Fig. 1), in which the decay of a large X-ray flare was observed. The intensity decreased from 80 to 40 PCU c/s (or 32 to 16 mCrab) over a time interval of 4 hours. The X-ray hardness ratio, shown in the lower panel, indicates that there was only a slight "softening" of the X-ray spectrum during this event.

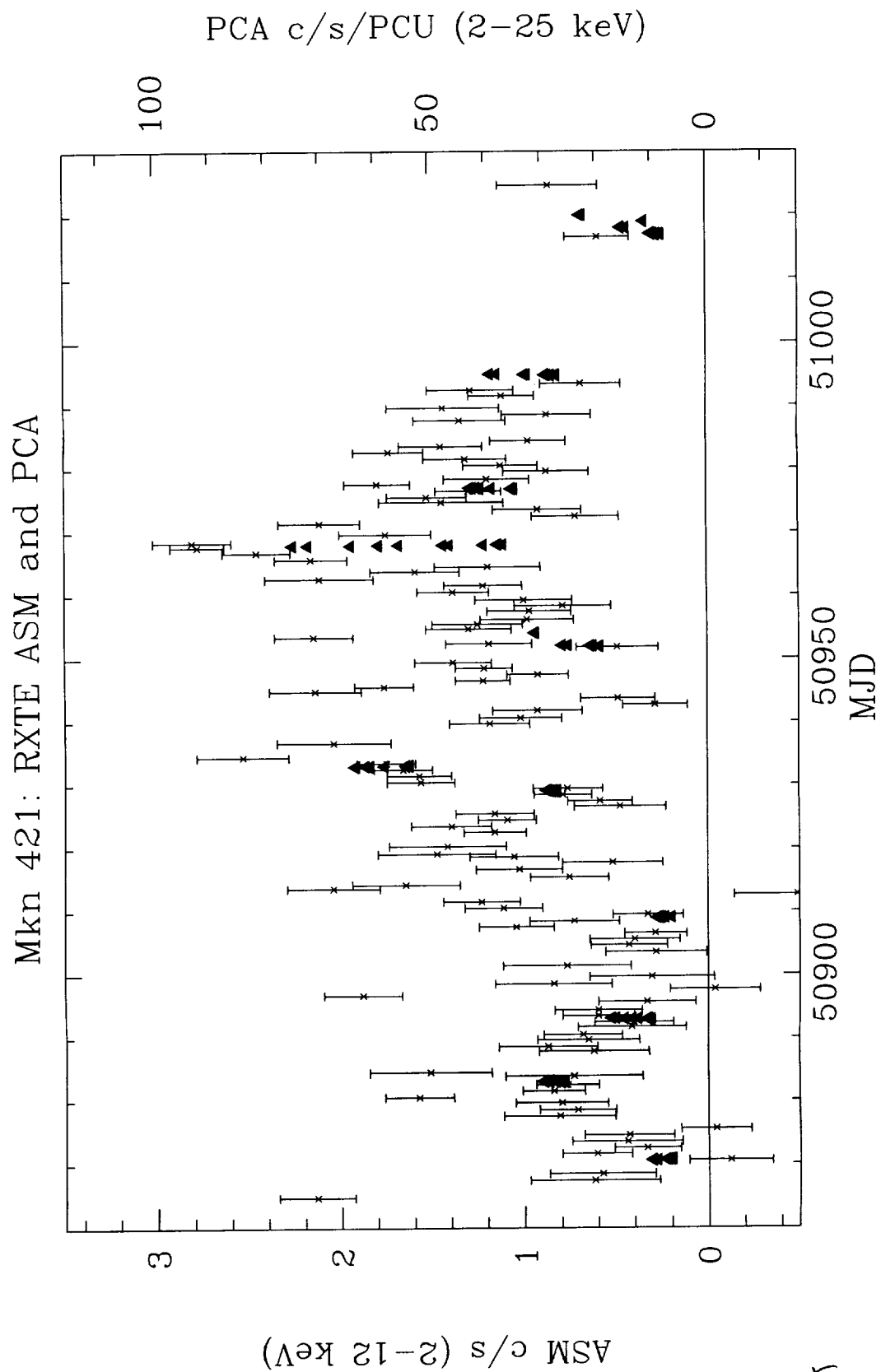


Fig. 1

MKN 421 RXTE PCA

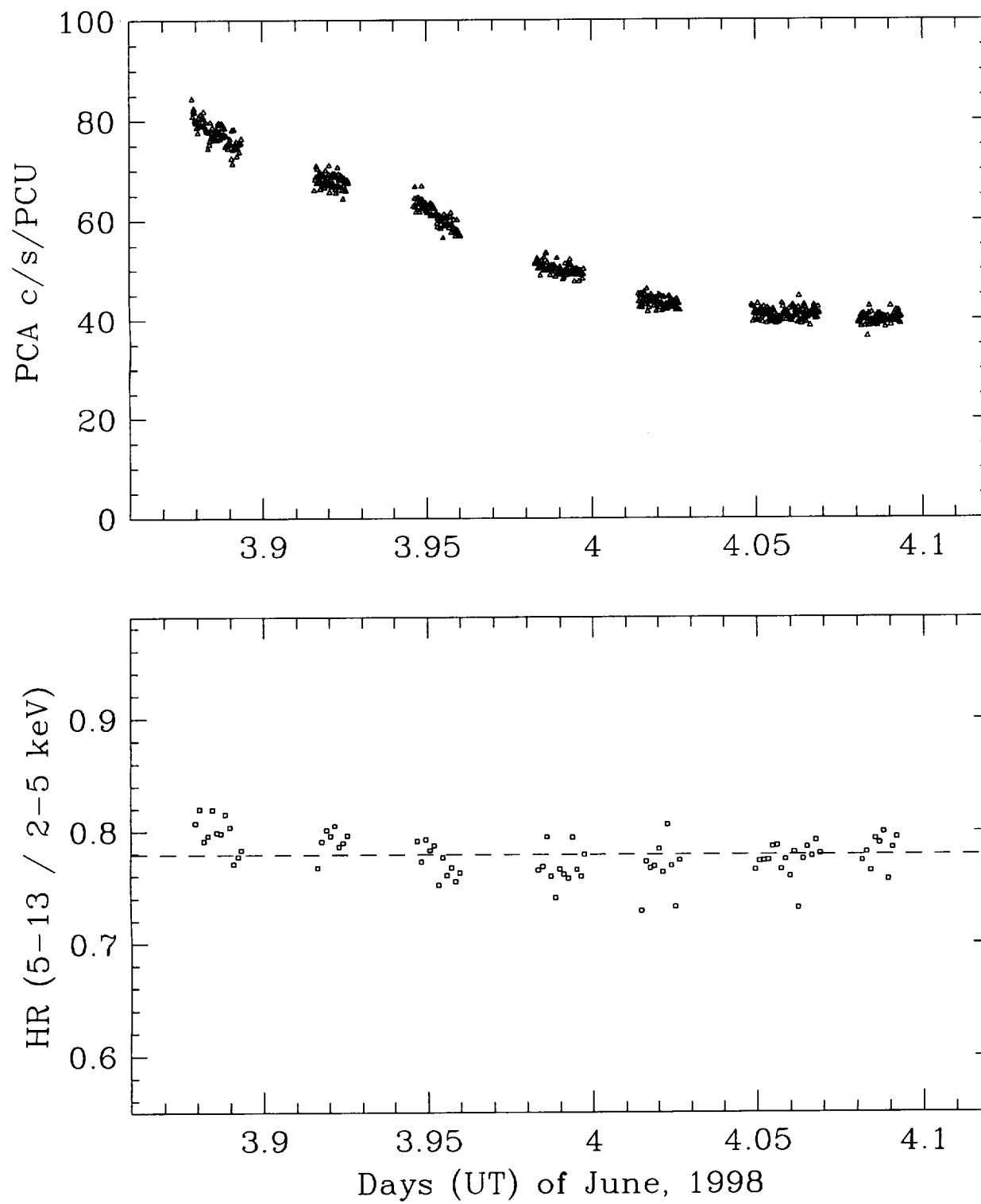


FIG. 2